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# Terms of Reference

# National Hydropower Sustainability Assessment

## Background

*<Climate adaptation in the country, climate adaptation needs, energy sector in the country, power sector vulnerability, existing hydropower plants, hydropower vulnerability, rationale for the project.>*

## Objective of the Study

The objective of the consultancy services is to assess the sustainability of existing and identified hydropower schemes in the [country]. The specific objectives are to:

* Assess the impacts of climate change on the future production of power from hydropower plants in the [country];
* Assess the impacts of upstream and downstream anthropogenic activities on the future production of power from hydropower plants in the [country], and
* Propose concrete adaptation investments and capacity development to make existing and identified hydropower schemes in the [country] more sustainable.

## Overall methodological approach

The assessment will in its major part be conducted as a desktop study, in which hydropower production from all existing and future identified hydropower plants will be simulated under carefully selected scenarios comprising three principle future conditions:

* Current anthropogenic influence and historical climate
* Current anthropogenic influence and projected climate
* Future anthropogenic influence and projected climate

Historical and future climate will be described with existing historical data, augmented by globally available data from the Climatic Research Unit (CRU) (augmented by locally monitored data) and climate change models. Historical trends and projections of anthropogenic influence will be based on studies of satellite imagery and census data. Hydrological and power simulation models will be used to calculate power production under different scenarios and to describe the uncertainties involved in both climate and anthropogenic projections.

One case study will be chosen in which a more detailed assessment of the water resources management and operation rules will be conducted to provide concrete suggestion of adaptation measures in the upstream catchment area and improved operation of the hydropower plant. The recommended adaptation measures will also provide guidance to similar measures to be taken in the other hydropower catchments in the [country].

## Scope of Work

### Inception and data compilation

The consultant shall mobilize the team and arrange for an inception visit to [country]. The consultant shall hold start-up meetings with the Client, the [donor] and relevant stakeholders. The consultant shall compile and review relevant previous studies, maps, and data.

The consultant shall create a comprehensive picture of the power sector in [country], with a focus on the role of hydropower. The existing power master plans, together with the [electric supply company] and the [Ministry in charge of energy and minerals], should be used to list all existing hydropower schemes and all future planned (up to 2050).

For all identified existing and future planned hydropower schemes, detailed information shall be compiled. This would include exact location, type of scheme, size and capacity, operator, operation rules, catchment area, water rights, etc. For each scheme the consultant shall also collect information on data availability for further detailed studies, such as availability of thematic maps, satellite or air photos, census data, land use, hydrological and meteorological data and water abstractions in upstream catchment.

The consultant shall propose which hydropower scheme shall be studied in more detail in terms of upstream anthropogenic impacts. The choice should be made based on identified challenges in water resources management and hydropower production in the recent year for the specific plant as well as access to detailed data and information. Interest has been expressed by the Government of [country] to do further studies on the [name] hydropower scheme. The choice of this basin for the case study should, however, be motivated based on the information compiled during the inception phase.

Based on the compiled data the consultant shall propose a final detailed methodology for meeting the study objectives. The consultant shall prepare an Inception Report including the meetings held, information compiled and updated methodology.

The consultant shall arrange, in association with the Client and the [donor], an Inception Workshop, with invited stakeholders from the Government, power industry, civil society, donors and other relevant organizations. At the workshop the consultant shall present the assessment and updated methodology and provide time for discussions and feedback.

Based on the feedback from the workshop and from the Client the consultant shall finalize the detailed methodology.

### Computation of natural historical inflow series

For all existing and planned hydropower sites the consultant shall compute natural hydrological inflows on a monthly basis for a historical period of at least 30 years length. The basis for the natural inflows should be historical hydro-meteorological data, augmented by global data (e.g. the Climatic Research Unit (CRU)), which should feed a hydrological model (rainfall-runoff model). This will enable a concurrent and complete time series of natural inflow for all existing and hydropower scheme in the [country].

As far as possible, locally available hydro-meteorological data, including historical records of reservoir levels and outflow data from existing dams, should be compiled and used to bias correct any error stemming from the global data because of its relatively crude spatial resolution.

Catchment areas from previous studies and information from [electric supply company] should be confirmed through global topographical data (e.g. Shuttle Radar Topography Mission). Local hydro-meteorological data should be quality analyzed as far as possible before being used.

The output shall be a concurrent series of natural inflows under historic climate with a monthly time step for at least a 30-year period for all existing and planned hydropower schemes the [country]. In addition, estimates of net reservoir evaporation (open surface evaporation minus rainfall) under historic climate shall be estimated for all hydropower schemes.

### Assessment of anthropogenic impacts

The consultant shall compile and quality control the information related to anthropogenic activities in the upstream catchment of each of the existing and planned hydropower schemes in the [country]. Preferably this data should be compiled and presented using Geographic Information Systems (GIS).

Based on previous studies and the compiled data the consultant shall describe the historic trend of land use and water abstractions in the catchments of all existing and future hydropower schemes. Based on the historic trends and additional information (not taking climate change into account) the consultant shall make a further projection of the trend up to 2050 for land use and water abstraction in each of the catchments.

Domestic and livestock water supply should be based on water rights and actual use data, if available, as well as census data and standard use per capita. Future trends should be based on historical trends and/or national statistics on population growth and increase in capita use.

Land use and irrigation development should be assessed through map studies and water rights data. If possible satellite images and aerial photos should be used to describe the historical trends. Future trends should be based on historical data as well as general expected expansion for agriculture and irrigation in the [country].

The consultant shall, based on the assumed trends in land use and irrigation, for each existing and future planned hydropower scheme, estimate the trend in water use for agriculture, including both informal and approved use of water. Information from the case study (see below) shall be used to inform the estimate of informal use of water.

Based on the assessment of anthropogenic impact the consultant shall compute two scenarios for future water use in the upstream catchment for each existing and planned hydropower scheme. The two scenarios shall represent the most probable and the high projections for year 2050.

### Detailed assessment of case study basin

For the chosen case study a comprehensive field study shall be conducted to complement and confirm data from the desk study. The catchment area upstream of the hydropower scheme should be visited and documented. Meetings and interviews with relevant stakeholders shall be conducted to understand the perceived trends in water availability and land use and cropping changes. The informal use of water through temporary abstractions from streams and rivers should be studied in detail.

For the case study it is a pre-requisite to conduct a detailed analysis of land use through satellite images (and aerial photos if available). Of special interest is the change of cultivated areas. Satellite images for different years should be analyzed to detect changes in vegetation and anthropogenic activities.

Local hydro-meteorological data from gauges and from the hydropower plant should be compiled. Historical data should be analyzed to detect possible trends, including the statistical analysis of rainfall contra river flows (e.g. double mass analysis) to detect changes in the runoff coefficient, which may indicate increased informal abstractions or changes in land use. Possible relationships between recent dry years and ENSO patterns should be assessed.

If the chosen case study scheme is an existing hydropower site, special focus shall be given to study periods when the scheme has failed, or been close to failing, to produce firm power. Visits to the power plant shall be conducted. Meetings with the operating engineers should be held to fully understand the operation rules and procedures of the power plant. Data on historic operation shall be compiled, if not available in the [city], and analyzed in detail.

In addition to changes in water use and flows, the chosen case study catchment shall be assessed with regard to erosion and siltation trends. If available, data on riverine sediment shall be analyzed to detect any trends. The trends in land use should be translated into risk assessment of increased erosion rate and increased riverine sediment transport. A sensitivity analysis on possible detrimental effects on storage capacity of the hydropower reservoir because of siltation under different sediment transport scenarios should be conducted.

### Climate change scenarios

The [donor] will provide the consultant with up to 75 climate change scenarios, including but not limited to the 56 IPCC Assessment Report AR4 projections (resulting from the combination of various Global Climate Models -GCMs- and emission scenarios) as well as a set of up to 15 Assessment Report AR5 Representative Concentration Pathways (RCP)/ GCMs for [country], at roughly a 50 km x 50 km resolution, including monthly temperature and precipitation forecasts for up to three future decadal periods over the 21st century, as a starting point for the analysis of future climate change scenarios. The climate projections obtained using raw GCM output will be re-gridded at 0.5x0.5 degree resolution reflecting the large number of AR4 and AR5 GCMs.

The consultant shall in addition compile any results and data available from previous studies, which has aimed at downscaling climate projections for the [country].

Based on the compiled climate change predictions, the consultant shall create principle climate change scenarios to apply to the historical natural series. The scenarios should be made for the time horizon of 2050 and for two climate change predictions reflecting the uncertainty in models and emission scenarios (most probable and high). For each of the four scenarios principle changes (e.g. in average and standard deviation), in relation to historic climate, in precipitation and temperature (and in consequence evaporation) and shall be defined. These changes shall be applied to the historical precipitation and temperature fed into the hydrological model assigned above to compute series of inflows to all existing and planned hydropower under projected climate change scenarios.

### Power simulations under different scenarios

The consultant shall set up a system analysis model for each of the existing and planned hydropower schemes in the [country]. The models shall be driven by the natural inflow but should include upstream anthropogenic impacts to calculate actual inflow into the hydropower plants. The system analysis models should include the simulation of reservoirs and reservoir evaporation. When hydropower schemes are located in cascades, a system model shall be set up for the entire river system.

For existing schemes, the existing operation rules should be used to configure the model setting. For planned schemes, firm power and operation rules should if possible be set based on pre-feasibility or feasibility studies. If these are not available, test runs should be made using historical series of inflows to set likely goals of firm power and operation rules. Environmental river flow requirements immediately downstream of the site should be taken into account. Existing downstream major water rights should be included in the operation rules, while projected use other than hydropower downstream should not be included.

Once the system models are set up they should be used to simulate power production under different scenarios. The following scenarios are proposed, but others may be proposed by the consultant:

* Base scenario: Historic climate and historic anthropogenic influence
* Natural scenario: Historic climate and no anthropogenic influence
* Probable 2050 scenario: Probable 2050 climate and Probable 2050 anthropogenic influence
* Worst 2050 scenario: Worst 2050 climate and Worst 2050 anthropogenic influence
* Anthropogenic 2050: Historic climate and Probable 2050 anthropogenic influence
* Climate 2050: Probable 2050 climate and historic anthropogenic influence

The results of the scenario simulations should be presented in tables and graphs in user-friendly way. Variables to illustrate are, for example, reliability (percentage of time steps failing to supply firm power) or total power production. The results should conclude the vulnerability of the existing and planned hydropower schemes to climate change and anthropogenic impacts on a national scale as well as individual schemes. Hydropower schemes that may be particularly vulnerable to either climate change or anthropogenic impacts should be highlighted.

It should be noted that the main goal with the power simulations is to illustrate the vulnerability of the hydropower schemes to future changes in climate and anthropogenic activities in upstream catchments. The emphasis is thus on accurately simulating the relative difference between scenarios. Since the models are to a large extent based on global data (e.g. from rainfall) and general estimates on anthropogenic impacts, the models’ ability to accurately describe the absolute performance of each scheme is very uncertain. Presentation of results should thus be emphasized on the relative changes in system performance.

### Proposed adaptation and improved operation

The results of the power simulations for a projected future portfolio of hydropower schemes in the [country] should be concluded and recommendations on hydropower’s role in a future power mix should be made. Adaptation measures such as, for example, diversifying geographical regions (and rivers) to locate planned hydropower schemes or to avoid certain regions should be proposed. The need for controlling future deteriorating negative effect of anthropogenic impacts on hydropower production should be clarified and recommendations on water governance should be provided.

For the chosen case study, the information obtained during field visits and meetings with stakeholders and plant operators should be used to propose possible concrete adaptation measures. These should include water and land management and conservation measures as well as possible changes in operation rules and possible seasonal forecasting for improving reliability of providing firm power. The set up system analysis model for the case study area should be used to test improved operation rules. Adaptation measures should be described in detail and cost-estimated and be prioritized to give concrete suggestions on investment plans for the case study scheme.

The identified adaptation measures in the case study catchment and scheme should be generalized to give recommendations for possible adaptation measures at other hydropower schemes in the [country]. Based on the results of the power simulation an action plan for prioritized further detailed studies/areas to define concrete adaptation investment should be proposed.

### 4.8 Reporting and workshops

The consultant shall make clear and concise reporting of the results. Reports should be written in [language]. In addition the executive summaries of the Hydropower Vulnerability Report and Hydropower Sustainability Report should be translated to [language].

The consultant shall arrange three workshops and associated reports:

* An Inception Workshop should take place within two months of commencement of the consultancy. This workshop aims to agree on the final detailed methodology of the project. The draft Inception Report shall be delivered at least 7 days prior to the workshop.
* A Hydropower Vulnerability Workshop should take place 12 months after commencement of the consultancy. This workshop aims to present the complete results of the power simulation under different scenarios, including conclusions on hydropower’s vulnerability to climate and/or anthropogenic changes in the [country]. The draft Hydropower Vulnerability Report shall be delivered at least 14 days prior to the workshop.
* A Hydropower Sustainability Workshop should take place 17 month after commencement of consultancy. This workshop aims to present the final vulnerability report and to present and discuss a proposed adaptation program. The draft Hydropower Sustainability Report shall be delivered at least 14 days prior to the workshop.

All workshops are assumed to be held in [city] and include up to 50 participants from Government, donors, civil society organizations and the private sector. A handout consisting of a description of the projects and the Executive Summary of the reports should be provided to all workshop participants. Following each workshop the draft reports shall be updated and finalized, considering received feedback.

In addition to the main reports, the consultant shall deliver bi-monthly Progress Reports to the Client and the [donor]. These should be short concise reports, focusing on progress of the consultancy activities compared to the previously agreed. For each workshop a short report shall also be submitted including a participant list, main discussions held and how the feedback has been incorporated into the final reports.

## Deliverables

The deliverables will be three main reports that shall have the following recommendations to the Government of Tanzania:

* An Inception Report, which will give detailed methodology of the study;
* A Hydropower Vulnerability Report, which will give conclusions on vulnerability to future hydropower production in the [country] because of climate change and/or anthropogenic impacts in upstream catchments. It will further give recommendation for Government of the [country] on hydropower’s role in the general Power Generation Master Plan.
* A Hydropower Sustainability Report, which will give concrete recommendations to the Government of the [country] on necessary adaptation measures in upstream catchments and in the long-term operation and maintenance of hydropower plants to make these sustainable.

All reports shall be delivered in 10 hard copies (color printed) as well as in digital format (PDF and MS Word).

## Consultant Qualification

The consultants should be an internationally recognized firm, supported by local expertise, with experience in water resources management, climate change and hydropower simulation in the [region], and preferably in the [country]. The consultant shall have the following key specialists in the team:

* Team Leader, Senior Water Resources Specialist: He/she should have an academic degree of Master or higher in water resources engineering or similar, and professional experience as Team Leader for similarly complex projects in the [region]. Experience of at least 15 years in the area of water resources management and at least 10 years as a team leader is a requirement. Experience of team leading in [donor] funded projects is desirable.
* Water and Power Modeler: He/she should have an academic degree of Master or higher in water resources engineering or similar, and professional experience from water resources and hydropower simulation in the [region]. Experience of at least 15 years in the area of water resources engineering is a requirement.
* Geographer and Watershed Management Specialist: He/she should have an academic degree of Bachelor or higher in geography or related field, and 10 years of professional experience from water resources management projects in the [region].
* Hydropower Specialist: He/she should have an academic degree of Master or higher in civil engineering or power engineering, and 10 years of professional experience with hydropower projects in the [region].
* GIS & Remote Sensing Expert: He/she should have an academic degree of Bachelor or higher and 5 years of professional experience with GIS and remote sensing work.
* Climate Change Specialist: He/she should have an academic degree of Bachelor or higher in meteorology or climate sciences and 5 years of professional experience with climate change projects.
* Sediment Specialist: He/she should have an academic degree of Bachelor or higher in morphology or geography and 10 years of professional experience in erosion and sediment studies, preferably in the [region].

In addition to the key specialist, the consultancy team should include necessary support persons for data compilation, workshop arrangements, professional editing and reporting.

## Services provided by the Client

As an element of capacity development, the [electric supply company] and the [Ministry in charge of energy and minerals] will arrange for local experts to work closely with the Consultant’s key specialists. The [electric supply company] and the [Ministry in charge of energy and minerals] will identify qualified counterparts in their respective organizations to liaise with the consultant, respond to questions, supply unpublished information and reports, and assist with logistics and contacts for site visits.

The [electric supply company] and the [Ministry in charge of energy and minerals] will provide all documentation and in-house data related to hydropower in the [country] related to the project. The [electric supply company] and the [Ministry in charge of energy and minerals] will also assist the consultant with contacts and other relevant stakeholders. All costs for data and information, such as hydrological and rainfall data, sourced from other authorities, must be covered by the Consultant.

The [electric supply company] and the [Ministry in charge of energy and minerals] will facilitate provision of site access to the hydropower site chosen for the case study and will accompany the consultant during the field visits. The Consultant shall arrange transport and logistics for their own team during field visits.

The Client and other stakeholders will cover their own cost in regard to participation in project workshops. The Consultant shall arrange the workshops, including venue, food and beverages and needs to accommodate costs related to their own participation.

1. **Time and implementation plan**

The project will be conducted during a period of 18 months, expected to start in [month]. The consultant will work in close collaboration with the electric supply company] and the [Ministry in charge of energy and minerals] staff as well as a team from the [donor]. It is estimated that the total input in person weeks are 60 and the following time plan and deliverables is anticipated:

* Inception and data compilation: 2 months
* Assessment of anthropogenic impacts: 7 months after inception
* Case study - detailed assessment: 7 months after inception
* Climate and hydrological modelling: 8 months after inception
* Hydropower simulations: 12 months after inception
* Proposed adaptation measures: 16 months after inception
* Workshops to get feedback and distribute results: 3 (after 2 months, after 13 months, after 17 months)